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SPECIFICATIONS FOR MIRROR STEREOSCOPES

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Abstract Specifications for mirror stereoscopes are given for the properties connected with image formation, image recording, image quality and operational, mechanical, and economical aspects. The measurements are explained briefly and the results for a number of stereoscopes are discussed. No single figure or formula for the overall performance is given; the user is asked to weigh the various aspects and qualifications according to his needs.

Résumé Les particularités des stéréoscopes à miroirs touchant à la formation, à la perception et à la qualité des images font l'objet de spécifications qui couvrent aussi le système mécanique, le mode d'opération et l'économie d'emploi. Des explications sont données au sujet des mesures. Les résultats concernant divers stéréoscopes sont discutés, mais aucune tentative n'est faite de représenter la valeur pratique globale de chaque instrument à l'aide d'un nombre unique ou d'une formule. Il est laissé à l'utilisateur d'étudier séparément les divers aspects du problème, de voir lesquels lui importent vraiment, et de trouver ensuite quel stéréoscope répond le mieux à ses besoins particuliers.

Zusammenfassung Nähere Angaben über Spiegel-Stereoskope und deren Eigenschaften bzgl. Bildformung, Bild-Registrierung, Bild-Qualität, sowie operative, mechanische und ökonomische Gesichtspunkte werden besprochen. Die Messungen werden kurz erläutert und die für eine Anzahl von Spiegel-Stereoskopen gültigen Ergebnisse werden gemeldet. Es werden keine einzelnen Ziffern oder Formeln bzgl. der allgemeinen Leistung gegeben; der Benützer wird angewiesen, die verschiedenen Gesichtspunkte und Qualifikationen seinen Bedürfnissen entsprechend gegeneinander abzuwägen.

Why are specifications necessary? As the interpretation of aerial photography becomes more important, more attention must be paid to the stereoscope, in order to obtain a better idea of the possibilities and limitations of the interpretation of aerial photographs.

Specifications for Whom? For interpreters who need a better understanding of their key-instrument. Therefore we will consider the performance of stereoscopes from the user's point of view.

Specifications of What? Of Optical and Operational Properties. We will only measure how the instrument influences the observation of the object (paper-print) and whether it is convenient in use. We are not concerned with how it is designed, what special solutions and materials are applied and how it is produced.

How to obtain Specifications? Considering the stereoscope as a "black box", we do not need an exploded view of the optical and mechanical parts. The only way to arrive at specifications is to establish the properties of interest to the user, then to point out a way of measuring them and finally to judge the results (FIG. 1).

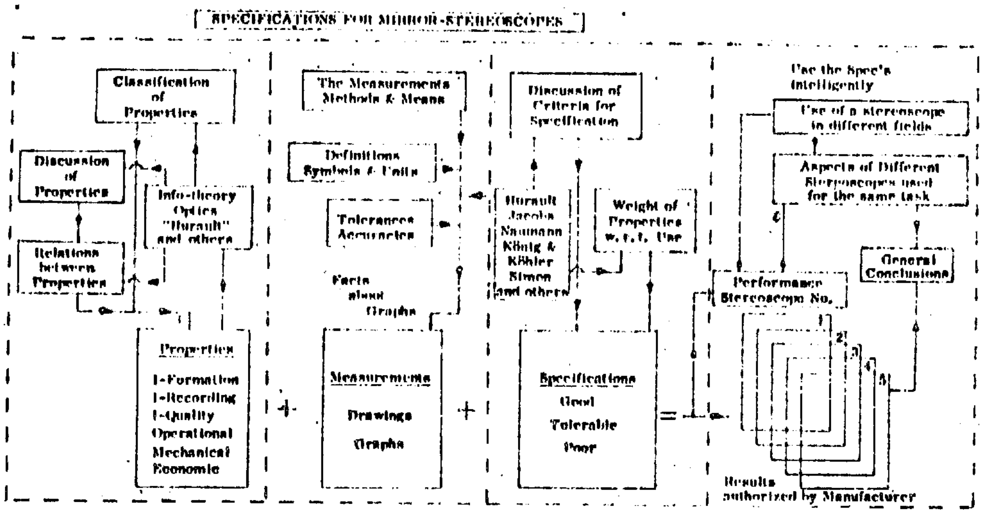

FIG. 1

Properties

A useful classification into groups of the various properties is:

Image Formation: Tracing back the rays of light from the retina to the object, the principles and properties involved in the forming of the image will be found. This is done firstly for monocular vision, after which stereoscopic vision is discussed and finally "scanning".

Image Recording: The actual recording by the brain is not discussed, but the eye needs a certain energy to function properly, so all influences on the brightness of the retinal image will be considered.

Image Quality: The influence of the stereoscope on the contrast of small detail in the transfer from print to eye will be expressed in a Modulation Transfer Function (M.T.F. or T.F.).

Operational aspects: The operator should not feel that he is looking through an instrument. A knob or adjustment possibility should have one function only and not influence other settings.

Mechanical aspects: Requirements as to stability, transportability, protection of mechanical and optical parts against rough handling are discussed.

Economic aspects: We mention price, time of delivery, service, *etc.*

On the complete specification sheets (pp. 48 and 49) each group contains 5 to 9 subdivisions.

Measurements

The simplest methods are used to measure almost every property just accurately enough. After all, this is not a production control, where tolerances have to be adhered to closely, but a search for significant statistics for stereoscopes. We established the procedure and routine on the stereoscopes in use at the I.T.C.; in future we will test new instruments along the same lines.

Specifications

It seems a risky task to judge the results of the measurements of each property and to classify them as "Good", "Tolerable" or "Poor". In one way or another it has to be done. We, therefore, attempted it, and *proposed* realistic specifications. Misinterpretation of the resulting "Performance-sheets" of stereoscopes cannot be avoided completely; we only hope that it will occur less frequently than persistent misbelief in qualities of various stereoscopes without knowing any facts except weight and price.

Results

Specifications for mirror stereoscopes (pp. 48 and 49)

Each property is presented, together with its qualification. The sheets are a guide for the testing agency, and may also be of value to the designer for future development.

Performance of stereoscope

Each stereoscope possesses a set of sheets indicating how well each property conforms to the proposed specification. Results for new stereoscopes will be published only after authorization by the manufacturer. No single figure for the overall quality of the stereoscope can be given.

Use of specifications

The specifications should be judged according to the task for which the stereoscope has to be used. This has consequences, not so much for the way in which the results are specified ("Good" is good and "Poor" is poor), but for the relative importance of the properties. Examples of when the qualification "Poor" is irrelevant are:

4. Observed area, when used for point transfer.
11. Eye-base (59–69 mm), when one has 65 mm eye base.
33. Illuminance at retina, when used for a short time only.
45. Useful focussing range, when one has normal eyes.
51. The Position of the eyepiece, when used for a short time only.
62. Protection against rough handling, when used by scientists.

On the other hand, a certain use can change the weight of some properties (*e.g.* in field work 62–66 are important) or even change some specifications (*e.g.* for point transfer, the useful magnification – in general 4× – might be 6× or more).

Conclusions as to the qualifications of a particular property

It is for the user to compare different stereoscopes, because only he knows the relative importance of the properties listed.

We will now consider more closely some particular properties. Out of each group one interesting property has been chosen.

2. *The position of the Exit Pupil* (the bright disk which can be seen when

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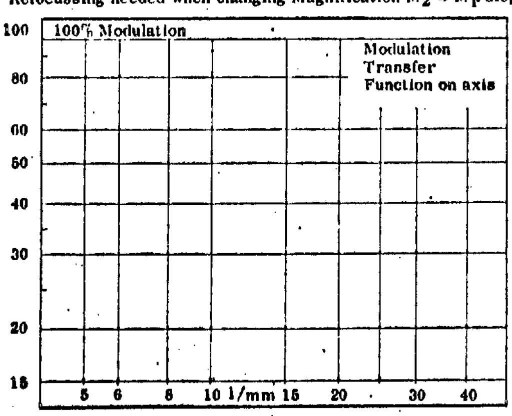
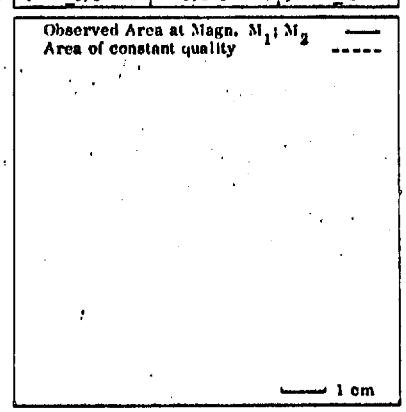
No.	Specification	Good	Tolerable	Poor
	Image Formation			
1	Field of view 2 u' .... (in radians)	> 0,9	0,7-0,9	< 0,7
2	Exit Pupil position : for 2 u' ≤ 0,8 rad (≈ 45°) .... mm	> 15	< 12-15	8-12
	(Eye Clearance) : used with spectacles .... mm	> 25	20-25	
3	Magnification M : Low M_1	0,8-1,0	1,0-1,5	0,6-0,8
	: High M_2	3-4	4-6	> 6
	: Ratio M_2/M_1	2-3	3-4	4-6
4	Observed area A (in % of 23 x 23 cm² print) at M_1	> 60%	30-60%	< 30%
	at M_2	> 10%	2-10%	< 2%
	Concentricity of areas (in % r_2)	< 20%		
5	"Optical axis" angle with perpendicular on print .... mrad	< 20	20-40	> 40
	Adaptation to Stereoscopy			
11	Eye-base + range of adjustment .... mm	65±10	64±8	64±5
12	Separation between corresponding points on prints .... cm	> 25	21-25	< 21
13	Parallax adjustment for height differences Δx .... cm	-1 - +3	±1	
14	Differences in Magnification between right and left (% or Δy) mm	< 1%;1/M	1-3%	> 3%;3/M
15	Model-curvature by Distortion (subjective)			
16	Rotation of one image to the other .... (milli-radians)	< 10	10-20	> 20
17	Re-orientation when changing $M_2 \to M_1$: Δy .... mm	< 1/M	1/M-3/M	> 3/M
	: rotation .... mrad	< 10	10-20	> 20
18	Observed area of stereo-model (in % of A (point 4))	> 90	80-90	
	Scanning and Double Scanning			
21	Scanning : parallel shifting of	prints	opt. axes	scope
22	Parallax adjustment Δy (mm) (Δx is less critically)	> ±10		
23	Y-parallax introduced by non-parallel scanning .... mm	< 1/M	1/M-3/M	> 3/M
24	Total area which can be scanned .... cm	20x23		
25	"Optical axis" angle with ⊥ on print when scanning .... mrad	< 20	20-200	
	Image Recording			
31	Size of exit pupil diameter .... mm	3-4	4-5	2-3
32	Transmitivity of stereoscope for white light	> 50%	40-50%	25-40%
33	Illumination at retina in % of unaided vision	> 50%	25-50%	10-25%
34	Flare as % of average brightness (luminance) of 23 x 23 cm²	< 3%	3-10%	10-20%
	(measured on area with Ø = 1/M cm) of 10 cm²	< 2%?	2-5%?	5-10%
35	Illumination under practical conditions (subjective)	easy	moderate	hard
36	False images .... (subjective)	no	at edge	at centre
37	Direct Flare into the eye .... (subjective)	no	some	more
	Image Quality			
41	Transfer Function approx. by a Gauss-TF: → 2σ of SF .... μm	< 15	15-25	> 25
42	Spatial frequency at 50% contrast .... lines/mm	> 35	20-35	< 20
43	Difference in Image Quality between x and y direction	no	10%	10-20%
44	Central area of good Image Quality (% of A (point 4))	> 90%	50-90%	< 50%
45	Useful focussing range of eyepiece .... dioptre	±6	±5	one < 5
46	Refocussing needed when changing Magnification $M_2 \to M_1$ dioptre	< ±0,5	0,5-1	> ±1





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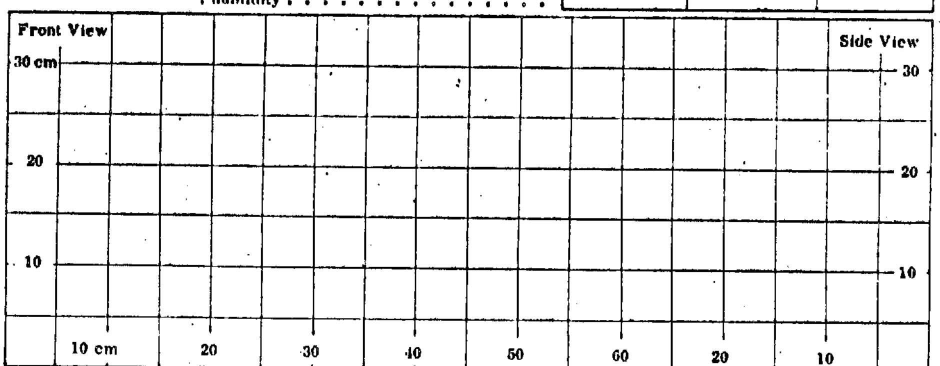
			Good.	Tolerable	Poor
	Operation and Handling				
51	Eyepiece position (exit pupil)	.1: angle with horizon α°	10-50°	30-60°	> 70°
		.2: height above table . . . cm	~32	depends on α etc.	
52	Adjustment of eyebase	: ease of handling (h hand; t turn)	1 h; 1 t	2 h; ~/slide	
		: calibration in mm	yes	obscure	no
53	Focussing	: ease of handling	1 turn		2 hands
		: calibration in dioptre	not	acc. ± ½	not acc.
54	Changing Magnification	: with + without binocular	1 handling	2 handlings	3 handlings
		: binocular $M_1 + M_2$	1 handling	2 handlings	3 handlings
55	Position of Prints	within easy reach and sight	easy	moderate	hard
56	Scanning in order to	observe different areas	1 handling	2 handlings	legs on print
57	Free space on table	.1: between leg and "optical axis" . . . cm	> 26	26-23	< 23
		.2: between mirror and print . . . cm	> 15	10-15	< 10
		.3: between table-edge and leg . . . cm	> 35	25-35	< 25
58	Parallax adjustment	: ease of handling	1 hand	2 hands	shift of print
		: calibration for zero-setting	yes		no
59	Dove prism	: ease of handling	1 hand	2 hands	
	Mechanical Aspects	Tested subjectively on a comparative basis			
61	Stability against vibration	: when adjusting a knob			
		: when moving or scanning			
		: when changing magnification			
	equiped with	adjustable leg for levelling			
62	Protection against rough handling	: of the mirrors			
		: of other optical parts			
		: of critical mechanical parts			
63	Protection against	: dust and smoke when in use			
		: dust and smoke when not used			
		: humidity			



64 Complicated or simple construction and use: Spare parts:
detachable accessories:

65 Weight of stereoscope ....kg; of stereoscope + case ....kg.
Size of case ..... x .... x .... cm³; Quality:

66 Other accessories: Maintenance:

67 Points of wear and tear: mechanical: Optical:
Expected Life:

68 Use: Short or prolonged use per day; Laboratory + Office; Production Room; Educational use;
Field use-Tropical or Moderate Zone.

69 Parallax Bar available: ; Quality: ; Remarks:

Economic Aspects:

71 Price of stereoscope D.G.: Price complete D.G. ITC
72 Delivery time : $ DELFT
73 Service DATE
74 Constant Quality : Constant Design : SIGNATURE

looking at the stereoscope from a distance), measured with respect to the last glass surface. This property is of great importance, because the pupil of the human eye should coincide with the exit pupil of the instrument in order to use the total field of view. An eye-clearance of 15 mm (when using spectacles, 25 mm) is sufficient if the rim of the eye-piece is shaped properly. Most stereoscopes do not deserve the qualification "good" for this property.

16. *Rotation of one image with respect to the other*, caused by misalignment of mirrors and prisms, results in poor stereoscopy. Correction of the effect by counter-rotation of the print is not allowed when parallaxes have to be measured. The easiest way to measure the relative rotation of one image with respect to the other is by stereoscopic observation of two lines. Tolerances are specified for a normal field of view; an accuracy of ± 5 mrad can be obtained and systematic errors of 10 mrad can be checked with the help of a pocket stereoscope. Most stereoscopes receive the qualification "tolerable" or "good".

21. Although "*Scanning*" belongs more to the application of the stereoscope, it might well be an important aspect of the performance of the instrument for prolonged use. It is not the scanning itself which is tiresome, but the control by eyes and brain of the tolerable y-parallaxes. With scanning stereoscopes and the use of rectified prints, these parallaxes will be small and stereoscopy is maintained over the complete model. Maybe this is, in the long run, more important than a perfect image quality.

34. *Flare* is expressed as a percentage of the average illuminance of the print. It is caused by all optical surfaces and depends on such factors as the polishing and coating of the surfaces of lenses, and scratches and dust on these surfaces. Flare is measured with, for example, a densitometer; the result depends on the type of densitometer, the magnification and the area which is illuminated. The observation of details in the dark areas of the print is hampered by flare. Our measurements indicate that flare is one of the most important single properties of the stereoscope. Qualifications run from "good" to "poor".

41. *Image Quality* is expressed nowadays in Modulation Transfer Functions (see paper by WELANDER), so we determined the M.T.F. for the central rays ("on axis") for a number of stereoscopes. As expected, the Transfer Function of a stereoscope can be approximated by a Gauss Transfer Function. From this we derive the linespread function, also a Gauss function, which is specified when 2σ is given. This 2σ (in μm) has the physical meaning of the minimum width of a thin line, when seen through the stereoscope. The T.F.'s are comparable properties, because magnification is not incorporated. The qualification corresponds roughly to the performance of the optical design. The proposed specifications are based on the results of the measurements, because existing literature is of no help.

51. The *Position of the eyepiece* is of utmost importance to the operator who has to use the instrument for his daily work. The large arteries that nourish his eye and brain should not be constricted by a bent neck. Looking downwards at an angle of 45° seems to be the best; looking vertically downwards

(90°) is even worse than "poor". The proper height of the exit pupil above the table is related to the inclination of the eyepiece and to the operator's height.

64. *The Construction* and the use of the stereoscope should be simple and adapted to the user; we can think of a phrase like "functional design". *Spare parts* are useful, but are also an indication that the design is not perfect. *Detachable accessories* are a source of trouble.

This paper was presented with the idea that the stereoscope deserves more attention from the designer and the user. We have proposed a consumer's test and are looking forward to useful discussions from both parties concerned with this "simple" instrument. A publication on the measurements and the qualifications is in preparation.

Discussion

P. O. FAGERHOLM (Sweden) considered Mr. HEMPENIUS' specifications very valuable as a start for a discussion on the subject. The answer to his further questions was that, so far, no contacts had been made with the International Standardization Office or with Commission I of I.S.P. Asked whether he would actually start a classification along the described lines, the author said that the proposed specifications are first to be tested by the interpretation section of the I.T.C.